FOREST ECOSYSTEM ANALYSIS USING A GIS*

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ABSTRACT

Forest ecosystem studies have expanded spatially in recent years to address large scale environmental issues. We are using a geographic information system (GIS) to understand and integrate forest processes at landscape to regional spatial scales. This paper presents three diverse research studies using a GIS. First, we used a GIS to develop a landscape scale model to predict forest soil erosion rates given alternative forest management practices and weather conditions. Second, a GIS was used to evaluate the cumulative impacts of land use practices on water quality for a 4350 ha basin. Third, we used a GIS to store and manipulate complex data bases for modeling the influence of climate change on forest hydrology and productivity across the southern U.S. We anticipate the demand for GIS techniques will greatly increase because of the need to address increasingly complex ecosystem questions.

INTRODUCTION

The research branch of the USDA Forest Service increasingly addresses complex questions related to impacts on the environment. These questions vary in spatial scale from the watershed to the region, and at temporal scales ranging from months to decades. We address these questions through ecosystem measurement and modeling. Research at large temporal and spatial scales require that innovative methodologies be employed to manipulate and analyze measured data or model inputs and outputs. A Geographic Information System (GIS) is a powerful tool that we can use for all phases and scales of ecosystem research (Everham et al. 1991). Various GIS's have existed since the early 1960's (Tomlinson et al. 1976), but only since the mid-l 980's have reductions in software and hardware costs and increased program flexibility made GIS's a tool viable for ecosystem research (Iverson & Risser 1987, Drayton et al. 1992). For these reasons, Lanfear (1989) concluded that the impact of GIS may be as important as the introduction of the FORTRAN programming language for understandiig environmental processes. This paper discusses the use of a GIS in three forest ecosystem studies in the southern U.S.

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STUDY # 1 SOIL EROSION PREDICTION

Traditional predictions of soil erosion are for whole watersheds, not for points within the watershed. Our research used a GIS to predict soil erosion under a variety of management practices (including road building, timber harvesting, burning, and creation of wildlife food plots), for a range of seasonal storm intensities. Through a GIS, model predictions of soil erosion can be spatially distributed across the watershed and displayed as map outputs. Maps will help the land manager to identify which sections of the watershed are most susceptible to soil erosion. The model can be rerun until a management strategy (e.g., filter strips, brush barriers, or altering the season in which management activities are conducted) are found which minimize (or reduces to an acceptable level) soil erosion. We used the universal soil loss equation (USLE) to predict soil sediment loss for a 1140 ha watershed

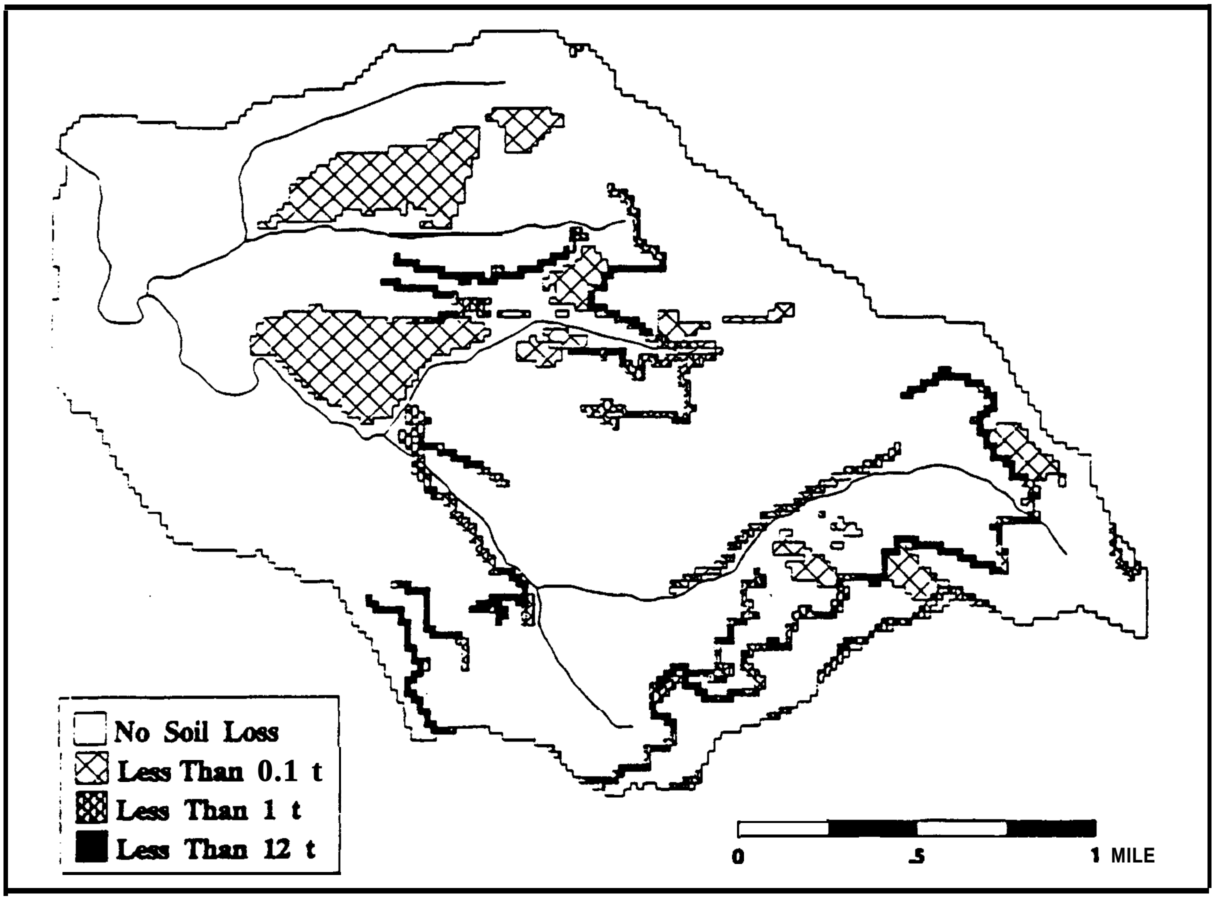

Figure 1. USLE Predicted Soil Erosion in a 1140 ha Watershed Given Poorly Constructed Roads and Average Annual Precipitation.

that contained various forest management activities (McNulty et al., 1995). The spatial grain size was $30m^2$ and the temporal resolution was seasonal.

In the previous example, we used a GIS with a soil erosion model to **minimize** the impact of forest management practices on stream water quality. However, despite our best attempts, many natural and anthropogenic events can degrade streams. Therefore, environmental planning and regulatory legislation require assessment of water quality changes associated with a variety of land uses. Methods for evaluating the relative contributions of **nonpoint** source pollution **from** different activities would be particularly useful to guide land use planning. Toward this goal we conducted research on the cumulative impact of land use practices on water quality of Coweeta Creek, a **fifth** order stream in western North Carolina (Swank and Bolstad, 1994). Managed forests occupy the upper **watershed;** subsequently, the stream flows through agricultural, recreational and residential lands.

Five water quality monitoring stations were located over the 8.7 km length of Coweeta Creek. Samples were collected during **baseflow** and **storm** events, and analyzed for chemical, biological, and physical parameters for 30 months. Using aerial photography and GIS technology, nine base spatial layers were developed for the watershed. Catchment characteristics (e.g., % **nonforest,** building density, agricultural area) were analyzed by applying a cartographic **buffering** operation in a GIS. Cartographic **buffers** were **then used** to character& **near-**stream conditions **from** each of the digital data layers. GIS generated spatial data showed good correlation with water quality criteria such as turbidity (Fig. **2),** bacteria populations, and NO, concentrations over the longitudinal stream gradient. GIS capability is essential in this type of research that entails complex spatial distributions of potential **nonpoint** sources of pollution.

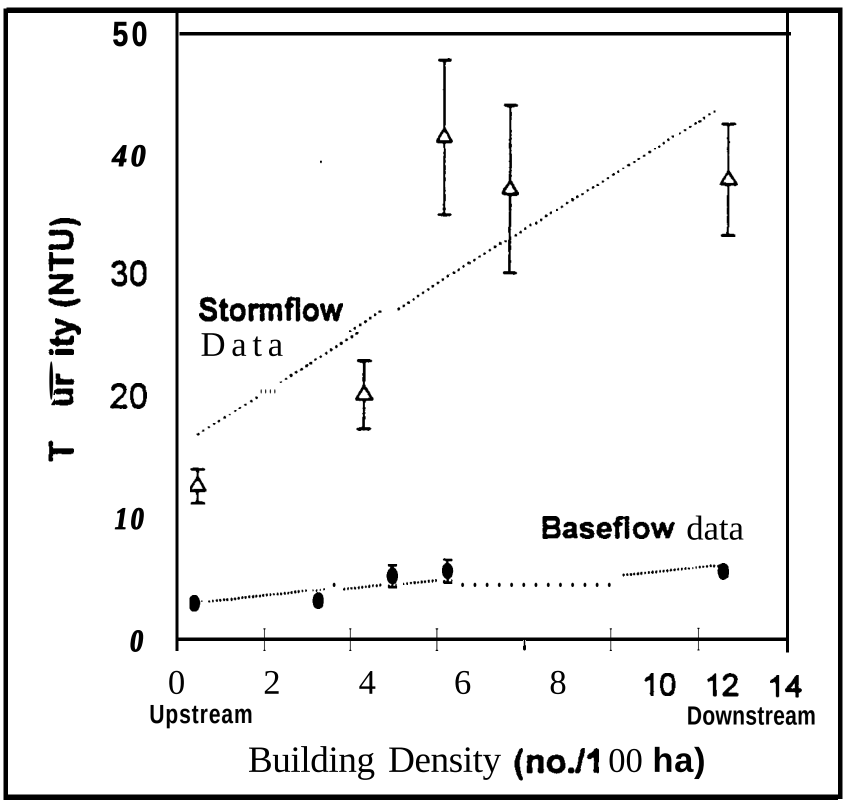

Figure 2. Relationship Between Stream Turbidity and Building Density.

During the next century, changes in the amount and distribution of precipitation, and increases in global surface temperature and atmospheric CO_2 concentration may occur (Mintzer 1990). These climatic changes could have profound impacts on forest structure and function across the southern United States. Due to the potential social and economic implications of these changes, the Forest Service is developing broad scale ecosystem process models to predict the potential impact of climate change on forest hydrology and productivity. To assess the possible effects of climate change on southern pine forests, we used a processed-based ecosystem model called PnET-IIS that used climate, soil and vegetation data as input variables to predict forest growth (McNulty et al. 1994). The development of databases necessary to define and validate these models are difficult to compile and use. The use of a GIS can simplify database management and model output interpretation.

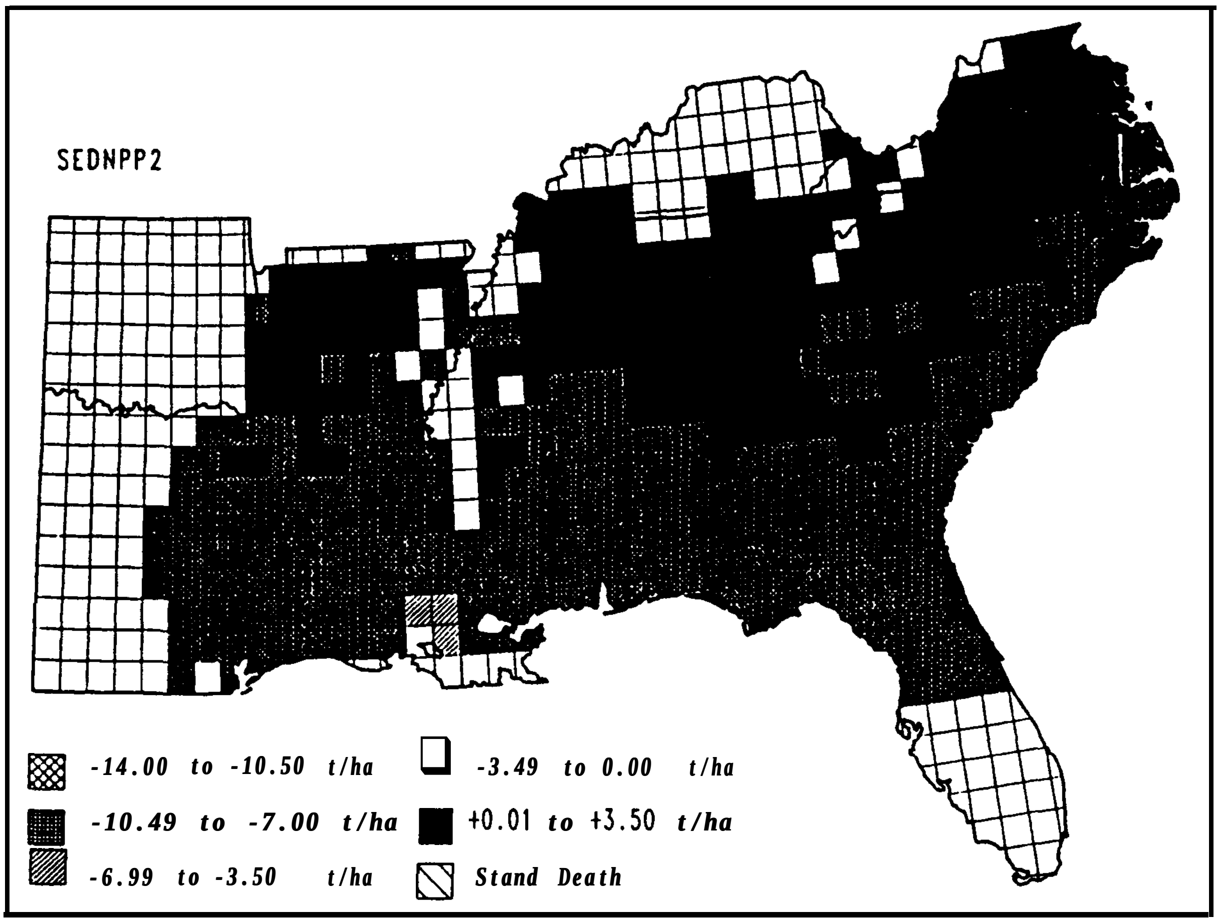

Figure 3. PnET-IIS Predicted Change in Southern U.S. Pine Forest Net Primary Productivity Given a Doubling of Atmospheric CO,.

Once we entered all model inputs (i.e., historic and predicted climate, vegetation coefficients), we used **PnET-IIS** and a GIS to predict how southern U.S. pine forest growth, measured as net primary productivity, would change given a doubling of atmospheric CO,, a **2°** increase in average monthly air temperature and a 20% decrease in total monthly precipitation (Figure 3).

SUMMARY

Whether for preventing, assessing or projecting ecosystem changes associated with natural or anthropogenic environmental impacts, a GIS is an important total for landscape scale research. The ability of a GIS to temporally and spatially store, manipulate and project data allows ecosystem researchers the ability to address environmental questions. These questions were not possible to answer a decade ago when these tools were not available. As research issues increase in scale and complexity, the need for GIS will also increase.

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